Space Weather Technical Forecast

Issued on Tuesday, 26 December 2023 at 01:29 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Numerous CMEs observed: Chance G1 periods, with a Slight Chance of G2, from the 27 December. Chance of M-class flares throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours, with only minor C-class flares, the largest was a C5 flare originating from AR3529 in the southwest quadrant. There are currently eight sunspot regions on the visible disc, one of which is a new and currently unnumbered sunspot region emerging in the southeast quadrant, although this appears to be small and stable at present. The largest sunspot region is AR3529 in the southwest quadrant (Eho/Beta), although has shown little activity in the past 24 hours. There remains a small filament immediately west of this feature, and flaring in the sunspot region is arcing across this, which has likely helped to generate the multiple Coronal Mass Ejections (CMEs) seen in the past 24 hours. AR3530 near centre-disc remains stable. Finally, some minor spots have developed around the main penumbral spot in AR3531.

As aforementioned the number of CMEs observed in the past 24 hours has been large and carries high uncertainty for their frequency and probable inter-connectivity.

The most noteworthy events are summarised as:

Firstly, a large filament eruption from the northwest disc observed around 24/1200 UTC. This has been analysed extensively, and although it largely passes above the ecliptic plane, there are a significant number of MOSWOC Enlil ensemble members that have glancing blows at Earth from around the middle of the UTC day of 27 December (Day 2).

Secondly, a high coronal dimming visible on AIA211 from the southwest disc (but not on H-Alpha), around 24/1430UTC. This feature has been analysed as crossing mainly below and ahead of the Sun-Earth line around the turn of the UTC day 27 into 28 December (Days 2 and 3), but again a glancing blow is considered possible.

Thirdly, a high coronal dimming in AIA211 around 25/0700UTC occurred to the immediate west of AR3533. This was not tied to any filament on H-alpha, but a CME appears to have been released. Provisionally, this is likely the most directly-aligned of any of the candidate CMEs with Earth, and early C2 imagery suggests a faint partial halo with a slight eastward bias. This has been analysed and is considered to be Earth-directed, with an arrival likely on the UTC day of 28 December (Day 3).

Solar Wind / Geomagnetic Activity: Solar winds, as measured by ACE and DSCOVR at L1, were Slightly Elevated throughout the period, ranging between 415 to 480km/s. Density was below to near average throughout, around 10ppcc. The IMF was steady and weak, peaking at 6nT, with the all-important north-south component also weak, ranging from +6/-6nT. The phi angle was variable, but mostly positive (away from the Sun). The net result of the above solar wind measures was for Quiet (Kp 0-1) geomagnetic activity throughout the period.

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Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at Background levels.
GOES16 high energy (greater than 2MeV) electron flux was mostly at Normal Background levels, occasionally rising to Moderate. The 24-hour fluence was below Active throughout and declining, with the 26/0001UTC observation being 3.11e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is forecast, with an ongoing Chance of isolated M-class X-ray flares.

Solar Wind / Geomagnetic Activity: There has been a glut of CMEs in the past 24 hours, and there is now high uncertainty in the phasing of impacts during the second half of the four-day period especially. At least three have Earth-directed components, for a full discussion please see the geomagnetic activity section. Geomagnetic activity should be mostly Quiet early in the period, before increasing to reach Active or G1/Minor Storm intervals from Day 2 (Wed 27 Dec), with a Slight Chance of a G2/Moderate Storm, as a result of CME influences. No coronal hole fast wind feature in the forecast.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is at Background and likely to persist at this level, but with a Slight Chance of increasing given any further notable flares from AR3529 or other regions on the disc, especially as these move into the western hemisphere.

GOES16 high energy electron flux is expected to persist at mainly Normal Background levels, with the associated fluence remaining below the Active level.

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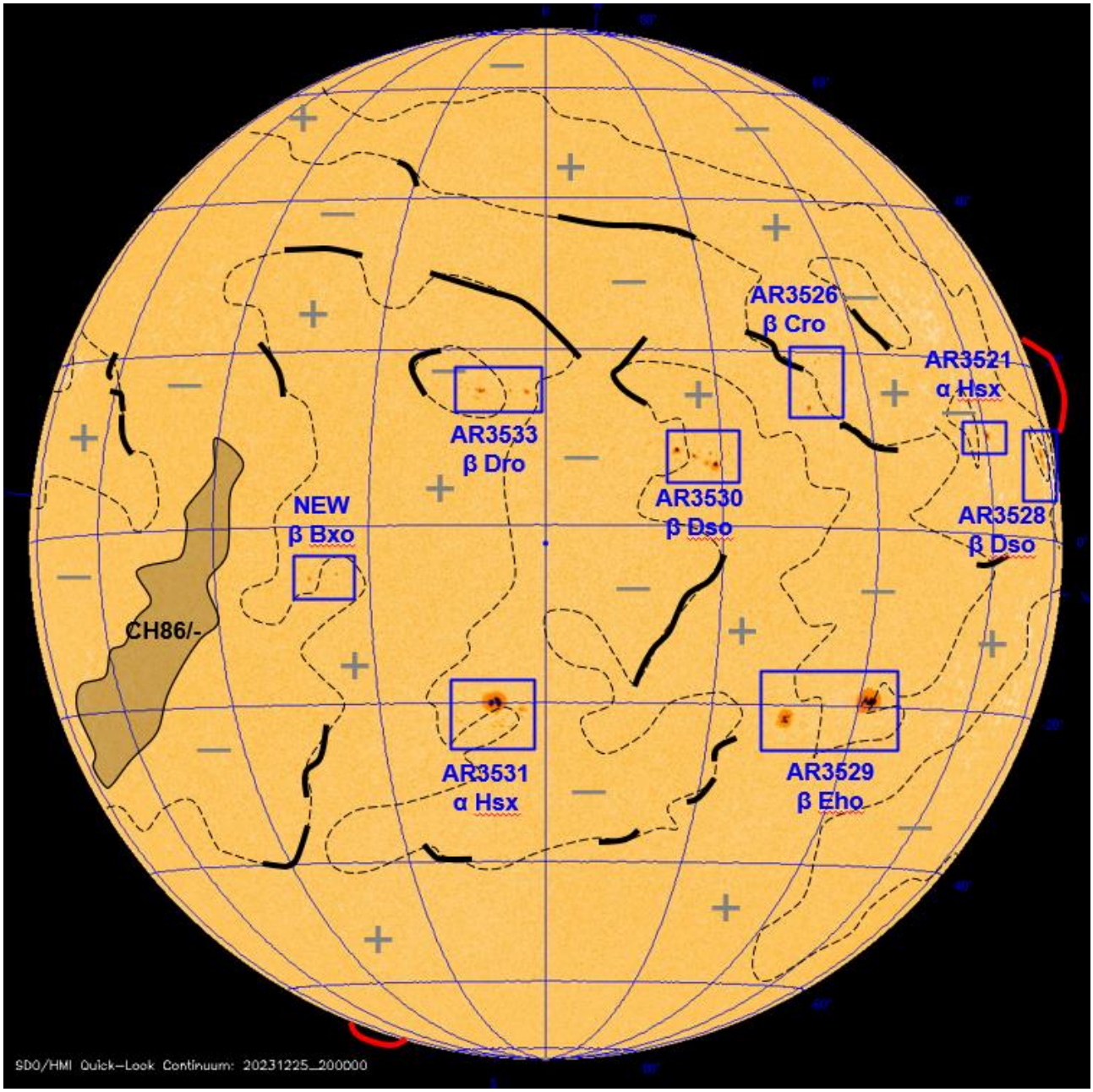
Figure 1. Solar Analysis Valid 25/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
No coronal hole fast wind feature in the forecast.

The number of CMEs observed in the past 24 hours has been large and carries high uncertainty for their frequency and probable inter-connectivity. The most noteworthy events are summarised as:

Firstly, a large filament eruption from the northwest disc around the start of the current reporting period (i.e. around 24/1200UTC). This has been analysed extensively, and although it largely passes above the ecliptic plane, there are a significant number of MOSWOC Enlil ensemble members that have glancing blows from around the middle of the UTC day of 27 December.

Secondly, a high coronal dimming visible on AIA211 from the southwest disc, around 24/1430UTC. This was flanked by M-class flares from AR3529, but the time the CME emerges from the occulting disc of Lasco C2 is a better fit for the event described above. This feature has also been analysed as crossing mainly below and ahead of the Sun-Earth line around the turn of the UTC day 27 into 28 December.

Thirdly, a high coronal dimming in AIA211 around 25/0700UTC occurred to the immediate west of AR3533. This was not tied to any filament on H-alpha, but a CME appears to have been released. Provisionally, this is likely the most directly-aligned of any of the candidate CMEs with Earth, and a partial halo with a slight eastward bias is now becoming visible on the current UTC morning's Lasco C2. This has been analysed and appears to be Earth-directed, also expected to arrive around the 28 December, possibly combined with the second CME mentioned above.

All considered - at least two of the above events have possible Earth-bound components. MOSWOC Enlil runs have been relatively volatile in the treatment of these, perhaps because of the sheer number of events. The model itself is now felt to be offering better treatment of fast winds - i.e. they now appear to be absent, as forecast, which increases confidence in CME transit times to 1AU. Earth may well see glancing impacts from above an below the ecliptic from the 27 December, else it could 'thread the needle' and be an island of relative calm despite numerous near-misses.

Despite the complexity of inputs, the actual distilled forecast is much simpler: geomagnetic activity should be Quiet over the Christmas period. There is then a Chance of G1, possibly a Slight Chance of a G2, from 27 December, although confidence is lower than is typical for this range.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	40	60	40
Strong	G3	No	1	1	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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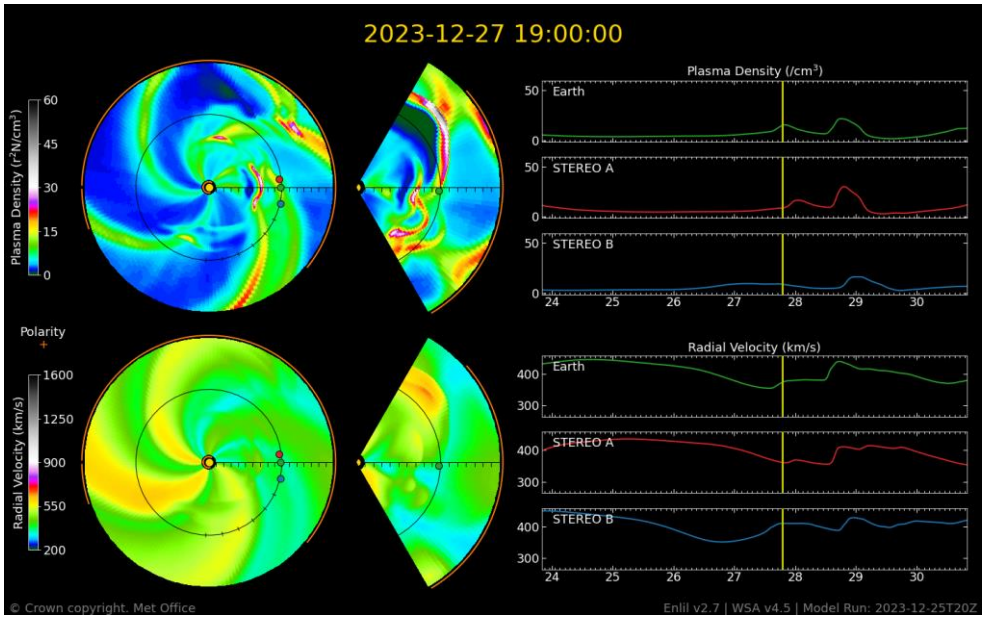
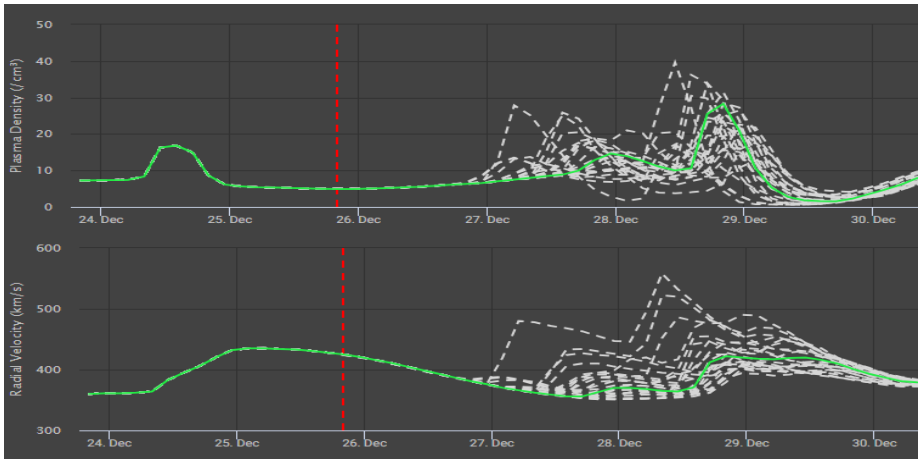
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/1732	Partial	Filament	NW	850km/s	27/1200UTC +/-12hrs	Low confidence, glancing blow
24/2224	Partial	Filament	SW	572km/s	28/0600UTC +/-12hrs	Low confidence, glancing blow
25/0700	Partial	Filament	NE centre	538km/s	28/1400UTC +/-12hrs	Low confidence Hit or combined with CME above.

Figure 2: MOSWOC Enlil and ensemble shows multiple CMEs possibly giving glancing blows or a direct hit during the 27-28 December, but with low confidence.





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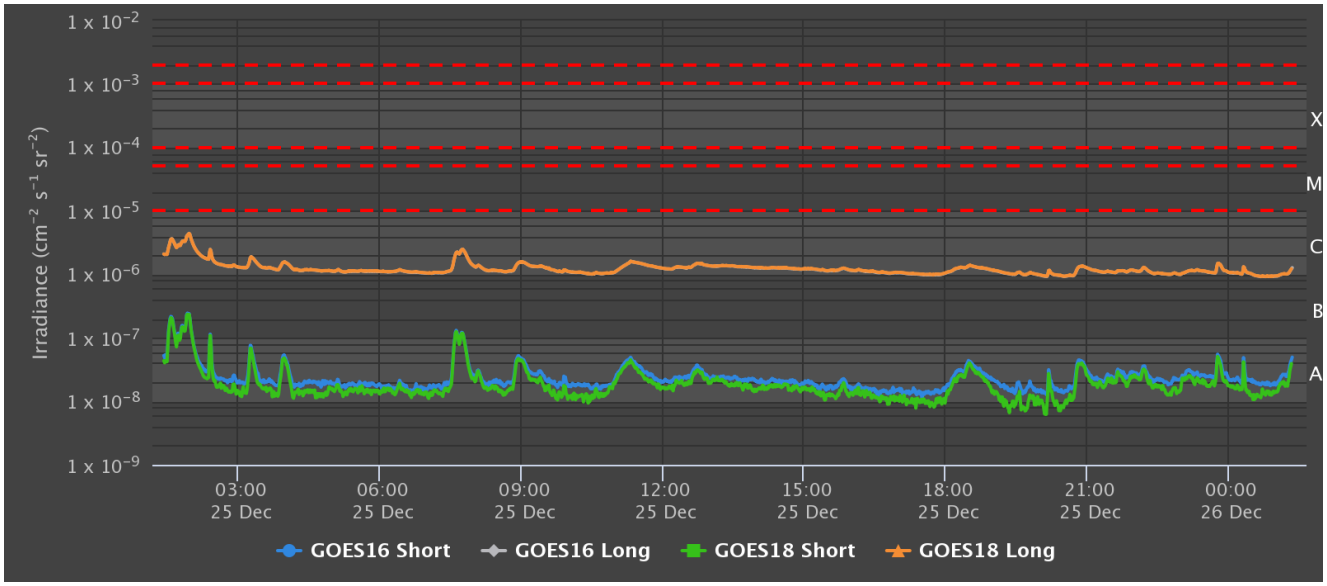
Radio Blackouts - X-Ray Flares:
Low to Moderate activity is forecast, with an ongoing Chance of isolated M-class flares.
There are currently eight sunspot regions on the visible disc, one of which is a newly emerged and unnumbered region in the southeast quadrant. The largest region is AR3529 in the southwest, which was the source of two M-class flares on the 24 December, but appears to be more stable at present, with a C5 the largest event from this region in the past 24 hours. The other main flare risk is AR3530 in the north-centre disc, which appears to have stalled in its growth, with only minor C-class flares observed from this region. The other six regions remain smaller and simpler, with a lower but non-zero chance of producing M-class flares.

An M-class flare was observed over the southeast limb on 24 December, and it remains to be seen if this is the precursor to a more active region rotating onto the disc. Along with a distinct area of magnetic looping visible on AIA171 in the northeast, this may suggest the potential for further arriving regions.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	30	30	30	30
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES X-Ray flares.



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 has been at Background, and is likely to persist at these levels. There is a slight chance of enhancement if any further M-class flare activity was to occur from AR3529, or from any of the other spots, particularly as they move into the western hemisphere.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 is mostly at Normal Background, with no further coronal hole influences featured in the forecast, although brief periods of Moderate flux are likely. There are then the CME glancing impacts possible from 27 and 28 December, and these are likely to further suppress observed flux at GEO until after this four-day period.

The associated 24-hour fluence is expected to persist below Active (1e8 pfu) as a result of the above. Regarding MOSWOC REFM, the fact that the current possible fast wind enhancement is not forecast nor a persistent feature, as well as the presence of three possible CMEs later in the period, will mean that although the initial trend is accepted, the rational is probably incorrect. MOSWOC REFM should not be followed in the second half of the period due to the CMEs, although the forecast low fluence count is probably correct.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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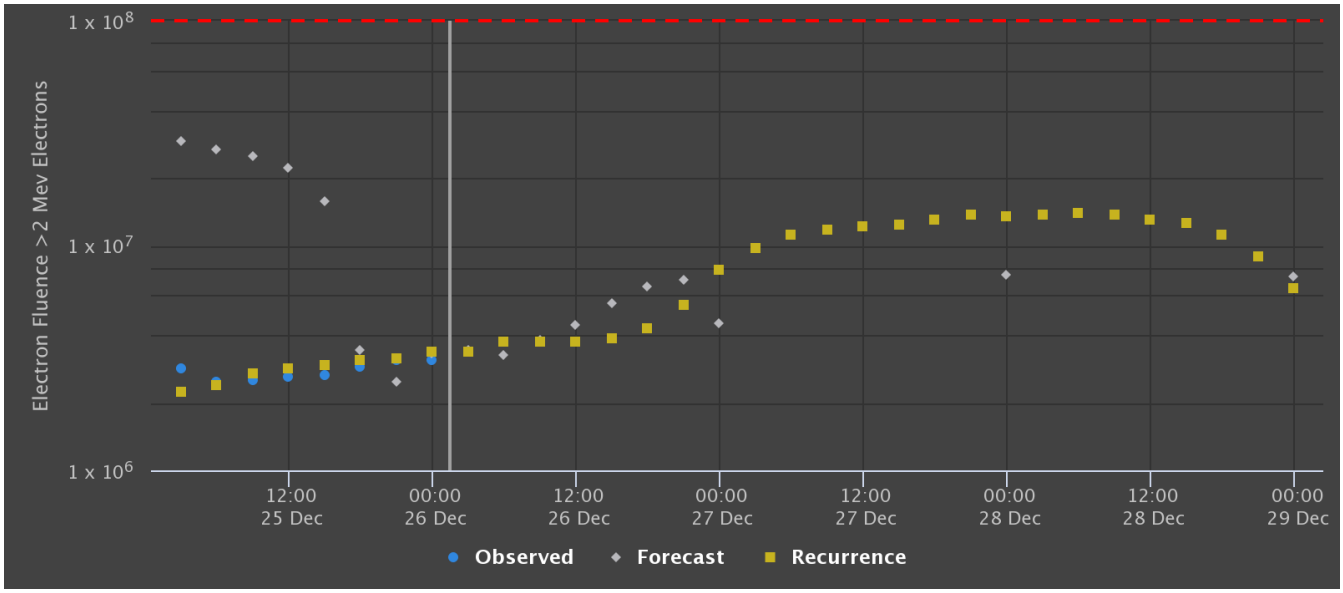
Figure 4: REFM electron fluence observations and forecast.



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